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A Hard Rain's a-Gonna Fall?

New Insights on Water Security and Fragility in the Sahel

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Abstract

Do Sahelian countries face specific risks of water-related conflict? Sahelian countries face growing fragility and climate challenges—especially those belonging to the Group of Five Sahel States (known as the G5 Sahel)—Burkina Faso, Chad, Mali, Mauritania, and Niger. This study examines how their relation to water availability and irrigation infrastructure factors in. It documents that the G5 Sahel countries, given their high baseline water scarcity and state fragility, face a higher risk of conflict over water resources compared to the rest of Africa. This is demonstrated through empirical analyses using geospatial data and exploiting (i) climate-induced variation in water availability, and (ii) an event study analysis of conflict trends, which sharply increased post-2010 in the region following the Arab Spring and the rise of the Boko Haram. Irrigated areas are found to be important for buffering against weather shocks but are also more prone to targeting during conflict events compared to non-irrigated regions. The evidence suggests that this reflects increased competition for scarce (fertile) resources between state and rebel groups on this climate frontier with a well-documented history of agro-pastoral conflict. Other regions of Africa are not found to experience similar conflict related to water resources. These findings are especially pertinent for informing projects and policy interventions in fragile countries as post-COVID-19 recovery and climate action plans are rolled out.

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1. Introduction

The Sahel region is renowned for its extreme desert climate as well as its frontline exposure to climate variability. The arid environmental conditions in the region wield a strong influence on the livelihoods of its large agropastoral population, many of whom live close to or at subsistence levels. As such, improving agricultural productivity, notably through irrigation investments, has been a central focus of the economic development strategy of the countries in the region and supported accordingly by international partners. Over the past decade, this strategy has also had to contend with an increase in state fragility rooted in geopolitical instability of the broader region. Faced with common economic challenges, the growing threat of terrorism and organized criminal activity, in 2014 five Western Sahel countries (Burkina Faso, Chad, Mali, Mauritania, and Niger) joined a framework for regional cooperation known as the G5 Sahel which has led to an unpreceded mobilization of resources for the region.

As noted in a recent World Bank report (World Bank, 2020), despite considerable advances, research has yet to systemically map drivers of fragility and conflict in a way that can support targeted prevention. This paper contributes to this objective by going back to a key locational fundamental: the availability of water. It aims to understand how the management of the resource, particularly through irrigation, interplays with fragility and thus informs policy makers and development practitioners on how to best optimize its use to promote socio-economic development. The topic is all the more relevant in the context of the concerted efforts towards a post-COVID-19 recovery as well as climate change mitigation and adaptation.

This paper documents how the relationship between availability of water resources and conflict has evolved in Sub-Saharan Africa with a focus on the G5 Sahel countries. To the authors' knowledge, this is one of the first to explicitly examine the dynamics between water availability and conflict in the region. The context of the Sahel region provides a unique setting for empirical investigation.[1] First, high baseline water scarcity has historically defined the livelihood strategies employed by the population (pastoralism, rainfed agriculture, etc.) as well as their cultural institutions. The expansion of centralized irrigation in the region is a more recent phenomenon. Second, while the region has known political instability in the past, the rise in extremism seen over the past years is distinct and ostensibly linked to factors external to the region, namely the geopolitical fallout in the aftermath of the Arab Spring to its north and the rise of Boko Haram in Nigeria in the south. This arguably provides an avenue for causally exploring the mechanisms that link water and fragility in the region.

We present two empirical approaches to document the relationship between water availability and conflict occurrence in the G5 Sahel countries. First, we build on previous findings of Harari and Ferrara (2018), henceforth referred to as HF, to show that the frontier climate of the G5 Sahel is particularly at threat of conflict caused by climate-induced variation in water availability. HF use gridded data for the continent of Africa to document a strong relationship between conflict occurrence and a drought index referred to as the Standardized Precipitation-Evapotranspiration Index, or SPEI. Using their data and a simplified version of their empirical model, augmented with interaction effects, we show that a large portion of the

[1] A larger body of literature can be found on the Sahel on issues related to climate shocks and malnutrition/ food security. An example of such literature is Alfani et al. (2015).

correlation between conflict occurrence and the SPEI documented by HF arises specifically from the G5 countries alone.[2]

Having established the particular importance of water availability in the Sahel region, we then turn to a different natural experiment that arises around the time of the Arab Spring. As a result of a long history of trans-Saharan trade and migration linkages, geopolitical turmoil in the northern Africa region also spilled over into western Sub-Saharan Africa and gave rise to increased violent conflict. Taking this as a plausibly exogenous shift, we use a difference-in-difference specification to show that in the countries of the G5 Sahel battle events were more likely to break out in locations where irrigation infrastructure was present. This differential trend is found to be robust to an empirical specification accounting for grid-cell fixed effects, country-year fixed effects and a set of relevant controls, such as the presence of cropland and population as well as climate variation. For other countries in western and Sub-Saharan Africa, found to the south of the G5 Sahel and thus less exposed to its "frontier" climate, we see the rise in conflict after the Arab Spring but no differential trend for irrigated regions.

Taken together the results suggest that the geographic specificity of the Sahel region further amplifies the strategic socio-economic value of water in the region. Changes in water availability induced by climate variation induce conflict. And when conflict breaks out due to a plausibly exogenous factors, violence is more likely to be targeted at regions equipped with irrigation infrastructure, particularly valuable due to its ability to buffer against fluctuations in rainfall-availability. Heterogeneity in the data also suggests that irrigated regions are more likely to be targeted during conflict outbreak when there is stronger resource competition due to population pressures or the presence of traditional uses of water resources.

2. Conceptual Framework

Water availability is a fundamental geoclimatic characteristic defining the livelihoods of many, either directly or indirectly – particularly in rural areas. In turn, the presence of water scarcity and variability can generate resource competition, and possibly lead to of conflict. Over time, the need to coordinate over the use of scarce water endowments gives rise to stable institutions to govern inter-personal and inter-group dynamics for sharing the resource. However, large and unanticipated changes such as those brought about by climate variability or geopolitical shocks can create shifts away from such cooperative equilibriums. Better understanding the relationship between water and fragility and how it has evolved over time and space can provide crucial insights into these dynamics. Indeed, a recent World Bank report suggests that issues surrounding water security can either amplify or mitigate the risks associated with fragility (Sadoff et al 2017). In addition, water security may itself be affected by fragility thereby creating the possibility of a conflict trap to arise and persist (Collier et al. 2003, Hegre et al. 2017).

Various empirical studies have documented the role of water scarcity and variability in determining conflict outcome (for a recent review see Damania 2020). Evidence from this literature provides further insights into the nexus of water and fragility. For instance, income losses generated by rainfall variation, or by water disasters such as droughts and floods, have the potential to increase conflict as individuals are pushed into more desperate circumstances during periods of scarcity (Miguel et al. 2004, Harrari and Ferrara 2018, Acemoglu et al 2020). Other findings however suggest that this relationship may be ambiguous (Couttenier

[2] Our simplified model is a stripped-down version of the spatial and temporal lags used by HF in their detailed model.

2014, Ciccone 2011, Sarsons 2015), or that income gains due to rainfall may even increase the likelihood of inter-group conflict if it increases the ability of extractive rebel groups to finance fighting capacity (Eynde 2018).

From a political economy perspective, the relationship between water and fragility can be looked at through the framework of “greed” or “grievances” used to analyze natural-resource-based conflict (Collier and Hoeffler 2004, Dube and Vargas 2014). Income losses arising from rainfall shocks or disasters may give rise to grievances due to the pursuant economic hardships and thereby increase individuals’ willingness to engage in conflict. However, such negative shocks also lower “greed” for the spoils of war (or the “predation” motive) as the financial viability of engaging in conflict reduces. Integral to these channels is the interaction of inequality and sociopolitical institutions and how these mediate cooperation and conflict. Beyond income losses, shocks affecting food security may generate the same outcome, particularly in areas of subsistence agriculture where self-consumption of agricultural production is prevalent, as is the case in rural areas of Sub-Saharan Africa.

A complementary perspective relates to water availability (including through irrigation) changing the dynamics around the “quantity” and “distribution” of *lootable* resources, and how complementary investment and policy reinforces those effects. Inequalities in resource endowments between different locations and population groups affects the likelihood of conflict breaking out (Berman et al 2017, Morelli and Rohner 2015). This suggests that the inequalities in water endowments can directly influence the onset and incidence of conflict. However, livelihood strategies and institutions have also evolved over the centuries to adapt to local ecological contexts (Dietz et al. 2003). Pastoralism, for instance, may be a strategy better-adapted to agroclimatic conditions that are not suitable for settled agriculture. The different property rights inherent in sedentary and pastoralist agriculture can then induce conflict over the control of land in regions settled by both types of farmers (Van Den Brink et al. 1995). Other evidence suggests that the presence of irrigation creates persistent inequalities in the productivity of agricultural land and can hinder cooperation and empower landed elites who may oppose democracy (Haber 2012, Jacoby and Mansuri 2018, Bentzen et al 2017).

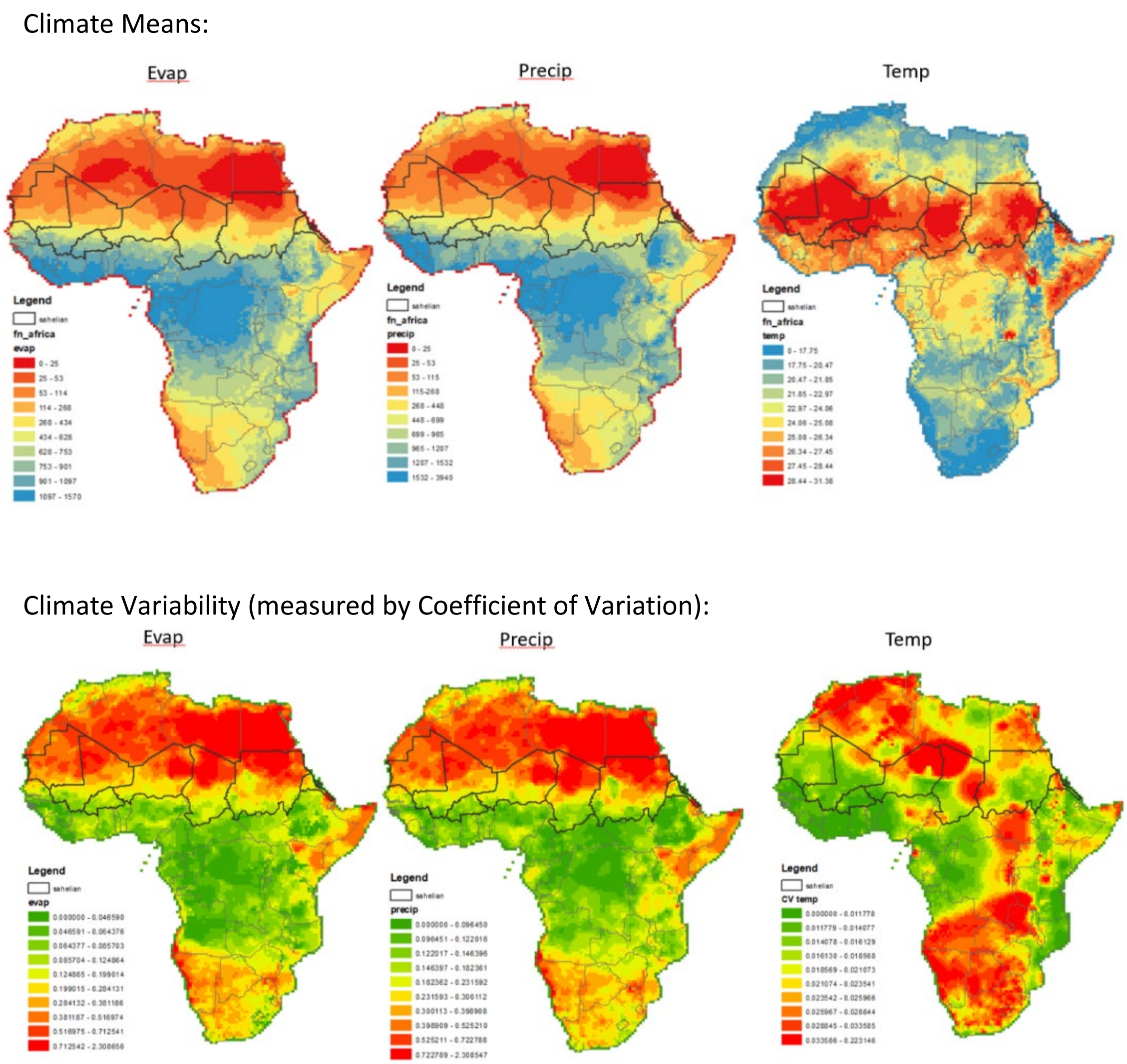
Two recent works are closely related to our findings. McGuirk and Burke (2020) differentiate between two types of conflict: “factor conflict” for the control of territory and “output conflict” for the appropriation of surplus. Focusing on Africa, they exploit exogenous price variations to show that producers in crop-producing regions face an opportunity cost of engaging in conflict (or “soldiering”) which offsets the incentive to engage in factor conflict, but higher crop prices in areas without crop-production induce both types of conflicts. Additionally, McGuirk and Nunn (2020) show that climate-induced rainfall variation can induce conflict when they disturb the traditionally cooperative equilibrium between transhumant pastoral groups and sedentary agriculturists in Africa. Specifically, they show that droughts in grazing pastures give rise to conflict when they cause pastoral groups to infringe on agricultural lands before the harvest, leading to competition for scarce land and water resources. The evidence presented in our paper contributes to this recent literature on the proximate causes of conflict in Africa, by documenting how conflict dynamics are affected when regional instability spills over into a region like the Sahel, which hosts a large (non-crop-producing) population of pastoralists and where large-scale crop production is a recent phenomenon enabled by irrigation infrastructure, and thus is prone to conflict over the control of territory.

Finally, this brings us to the role of water sector infrastructure such as irrigation and dams. These investments are made to buffer against rainfall variability and disasters such as droughts and floods. Hence, they serve as important adaptation strategies to hedge against the threat of conflict breaking out by building resilience of agricultural incomes to short-term water scarcity. They are also found to buffer against conflict risks arising from climate variation in the case of Africa (McGuirk and Nunn, 2020). However, it has also long been recognized that investments in such infrastructure may also heighten fragility if they foster inequality, rent seeking (Stanbury and Lynott 1992), and increase the *lootability* potential of those areas. Their design, especially in fragile settings, needs to account for such contextual realities to achieve their development objectives (Burney et al 2013, Woolcock 2014). In the absence of institutional arrangements necessary to manage and distribute the surpluses that accompany large-scale irrigation, regions equipped with such infrastructure may become targets when conflict breaks out, especially in a setting where a strong "predation" motive to control scarce (water) resources may dominate.

3. Regional Context and Background

Fragility in the Sahel is the result of complex factors, some with deep historical roots and others more recent and extending beyond the region. The former includes factors going from local level tensions and grievances (e.g., arising from land conflict) to national grievances of ethnic groups underrepresented or excluded from political decision-making (e.g., the Tuaregs). The latter includes the fallout of events

Figure 1: Means and coefficient of variation for climate variables.



happening on the outer edges of the region, such as those in Algeria (expulsion of Al-Qaeda in the Islamic Maghreb) and the indirect consequences of the broader Arab Spring and its indirect impact on trafficking related dynamics (arms, drugs – especially since 2005, contraband, and migrants). Additional factors such as a high population growth rate have wielded an influence on other factors including a large youth bulge heightening poverty and low employment issues to which climate vulnerability and now the COVID-19 crisis further contributes to form a dangerous "fragility trap".

It is not the purpose of this paper to review all these factors, and many other researchers have aptly done so before.[3] Rather, it draws the focus on the issue of water for three reasons. First, water has been overlooked as a separate factor. It tends to be lumped with other environmental factors as a resource, and with the issue of access to basic services when talking of water supply. Climate shocks are taken as a given vulnerability of the region and, except for the case of extreme weather shocks, given a coarse "background assumption status". Figure 1 above characterizes the climate on the African continent using data from Willmott and Matsuura (2001).[4] Specifically, the top panel plots a map of the means of annual evaporation, temperature, and precipitation over the 1990 – 2017 period in each location, while the bottom panel shows the inter-annual variability of these climate variables within a given location over the same period. The sharp spatial gradient in climate variables experienced in the Sahel region stands out, indicative of the fundamental nature of agroclimatic conditions in characterizing the region.

Second, most of the research available on fragility in the Sahel has been qualitative. This reflects data challenges found in Sub-Saharan Africa in general (limited granularity in available variables, sample size and time coverage etc.), and others more specific to the region – including important variation in population densities. Water data itself has long been known to be imperfect and requires triangulation to overcome poor in-situ data. Nonetheless, the comparative advantage of an econometric approach to this analysis is its systematic and reproducible approach combined with a search for causal inference that can help disentangle concomitant factors and events.

Third, an unprecedented mobilization of financial resources has been directed towards the region in recent years, prompted in large part by the 2012-13 Malian political crisis and the resulting militant Islamist occupation of the country's northern territory. This crisis has led regional and global leaders to coordinate against the spread of political instability in the region and beyond. Over the next three years, the World Bank alone plans to support G5 Sahel countries with funding totaling US$7 billion. A substantial part of those resources can be expected to either directly or indirectly involve water resources. The evidence presented in this paper seeks to inform these future engagements, as well as additional post-COVID-19 recovery efforts, to prevent lock-in effects and unanticipated spillovers, with lessons that may apply well beyond the region.

4. Data Sources

This section presents an overview of the various data sources utilized in the empirical approach presented in section 5. The first empirical approach, discussed in section 5.1, builds on data compiled by Harari and Ferrara (2018). HF utilizes gridded spatial data for the period 1997 to 2011 to present a plausibly causal effect of climate on conflict occurrence for the continent of Africa. Specifically, to measure the impacts of

[3] See, for instance Eizenga (2019) and Guillaumont et al. (2016).

[4] Inter-annual variability is measured by the coefficient of variation (= σ_i/μ_i , where i is the grid-cell).

climate they use the Standardized Precipitation and Evapotranspiration Index (SPEI) developed by Vicente-Serrano et al. (2010). The SPEI factors in both precipitation and potential evapotranspiration to capture the ability of soil to retain water, and thus outperforms other indices in predicting crop yields. The SPEI is expressed in units of standard deviation from each grid-cell's historical average (and thus has a mean of zero). HF measure yearly SPEI for each grid-cell as well as SPEI specific to the growing season of the main crop in a given grid-cell. Additionally, HF utilize data on conflict occurrence between 1997 and 2011 from the Armed Conflict Location and Event Dataset (ACLED), which records a wide range of conflict events such as protests, battles and rebel activities derived from war zone media reports, humanitarian agencies and research publications. As is standard in the conflict literature, HF code a grid-cell (i) as a dummy equal to 1 if the grid-cell experienced any conflict event in a given year (t). The data from HF on the occurrence of conflict and the yearly SPEI for the continent of Africa used by HF are presented in Figure A1 in the appendix. The analysis in section 5.1 also uses all time-invariant characteristics of grid-cells that HF also control for, taken directly from their data – these include cell-specific measures of elevation, roughness, area, presence of roads, distance to river, cell shared by multiple countries, border presence, presence of minerals, and ethnolinguistic fractionalization.

The next empirical approach presented in section 5.2 examines conflict breakout in West Africa more specifically, before and after the Arab Spring (circa 2011), covering the period between 1998 and 2017. This requires using data on conflict events directly provided by ACLED, since the HF analysis does not cover the post-2011 period. To focus the analysis on fragility arising from violent political clashes over control of irrigated territory, this section focuses on a narrower definition of conflict which captures only the occurrence of "battles" in ACLED, which is defined as "a violent interaction between two political organized armed groups at a particular time and location", with a grid-cell i being coded as a dummy equal to one if a battle occurred in year t. Figure A2 in the appendix plots the spatial distribution of the frequency of battle events in the countries of Western Africa, and for the whole African continent, at the 50km x 50 km resolution, which is the resolution of the main analysis in section 5.2. Additionally, to measure the share of each grid-cell that is irrigated at the start of the analysis period gridded, gridded data on the average area equipped for irrigation between 1990 and 2005 is taken from the FAO. The construction of this data set is described in Siebert et al (2015). Figure A2 also plots this data at the 1km x 1km resolution at which the raw data is available. To conduct the analysis, this raw data is aggregated to 50km x 50km by taking the average percentage of area irrigated in all smaller cells that fall within a larger grid-cell.

In addition to these main data, the analysis detailed in section 5.2 also employs various other time-invariant grid-cell level characteristics to control for possible confounds of climate and irrigation availability that may also be correlated with conflict. These include: the share of area with cropland and pastureland taken from Ramankutty et al (2008); population density in the year 2000 derived from the Gridded Population of the World data set (GPW v4); the presence of wetlands from the Global Lakes and Wetlands Database (GWLD v3) from WWF; and the presence of ethnic homelands of ethnicities whose historic economic activity is identified as being agricultural (see Michalopoulos and Papaioannou, 2013 for data description).

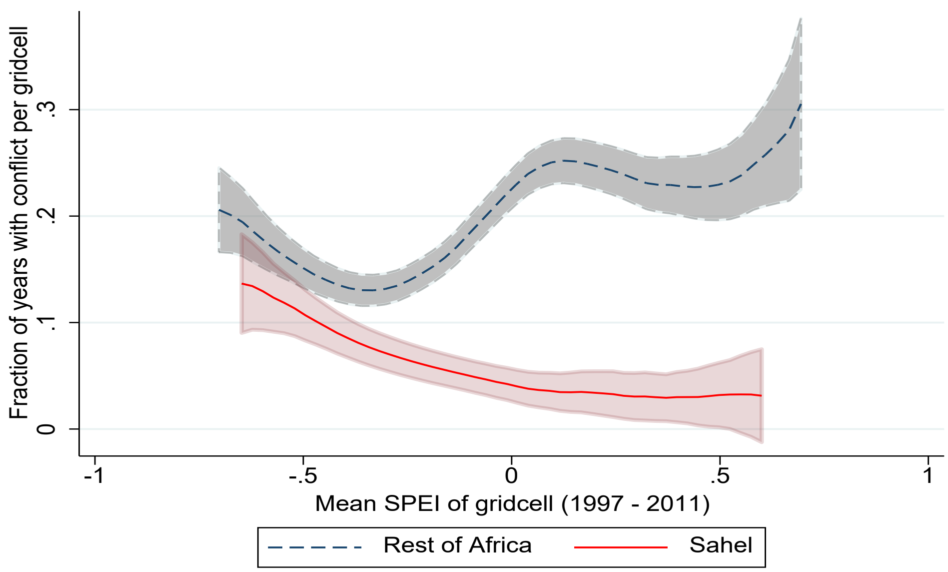
5. Empirical Approach and Results

Building on our conceptual framework, this section analyzes the relationship between water and fragility in the context of the Sahel region. We first show evidence that the region is historically at a higher risk of conflict related to variations in water availability. We argue that this is due to the high degree of water scarcity prevalent in the Sahel in comparison to other countries in Sub-Saharan Africa. This suggests a significant role for infrastructure investments in the water sector aimed at reducing the effects of climate variability, such as irrigation, in mitigating conflict risks. However, the benefits from infrastructure are also constrained by the economic and institutional environment. In that respect, we document evidence of a sudden onset of conflict that occurred in the group of countries known at the G5 Sahel after the Arab Spring, and how the political context of the Sahel region may have led to higher risks of conflict in areas with irrigated land, possibly resulting from an increase in the "potential lootability" of those areas, population density, or changes in local livelihood dynamics.

5.1 Climate Variation, Livelihood Shocks and Conflict

First, this section revisits the relationship between conflict incidence and climate-related variability in soil water-content documented by Harari and Ferrara (2018) – henceforth HF. Their research provides evidence that climate-induced negative income shocks in the African continent generate persistent increases in conflict incidence, and that such conflict spills over into neighboring regions. Using HF's gridded data on conflict and variations in water content of soil captured by the SPEI, we find the existence of a sharp negative relationship between the SPEI and conflict specifically for the countries of the G5 Sahel.

Figure 2: Relationship between mean conflict and SPEI for G5 Countries and the Rest of Africa, usig data from Harari and Ferrara (2018).



To build on this analysis, we start by looking at the cross-sectional relationship between the average annual SPEI of a grid-cell during years 1997 to 2011 and the fraction of years in which a conflict event occurred in that cell, separately for the G5 Sahel countries and the rest of Africa (Figure 2). The evidence here suggests the presence of a strong negative relationship between the SPEI and frequency of conflict for a given cell, but the correlation between *mean* conflict and SPEI does not account for country-specific differences in average climate and conflict experience that may be driving the relationship. It may well be that regions which have a higher average SPEI experience more conflict due to unobserved characteristics that are correlated with both variables, such as type of terrain.

To address the issue of unobservable covariates, the data on annual occurrence of conflict per grid-cell and annual variation in the SPEI are next analyzed through the following regression:

$$conflict_{ict} = \alpha + \beta \, SPEI_{ict} + \gamma \, SPEI_{ict} \times D_c^{G5\,Sahel} + \nu \, X_{ic} + \eta_c + \tau_t + \epsilon_{ict}$$

Where $conflict_{ict}$ is a dummy variable indicating the occurrence of any conflict event in cell i in country c in year t, $SPEI_{ict}$ is the value taken by the SPEI in that cell in the given year, $D_c^{G5\,Sahel}$ is a dummy equal to 1 if the grid cell falls within one of the G5 Sahel countries, and η_c and τ_t are a full set of country- and year-specific fixed effects. Additionally, X_{ic} contains a set of controls for time-invariant cell characteristics (also used by HF in their specification) that may be correlated with both climate and conflict: terrain, elevation, cell area, presence of roads, distance to river, presence of a country border, presence of any mineral resources and a measure of ethno-linguistic fractionalization. The regression allows for the examination of *contemporaneous* (as opposed to mean) correlation between conflict incidence and variations in the SPEI, after accounting for these time-invariant cell-specific cofactors that may be correlated with both conflict incidence and the SPEI.

The results suggest that for the base group (i.e., the rest of Africa), there appears to be no relationship between the SPEI and conflict incidence.[5] However for the G5 Sahel countries, this relationship is negative as indicated by the statistically significant coefficient of the interaction term that is also large in magnitude. The results (Table A1 - column 5) suggest that a 1 unit increase in the SPEI reduces conflict in the Sahel by 3 percentage points, but has no effect in the rest of Africa. That is, when rainfall is more abundant, conflict incidence in reduced for the G5 Sahel countries, unlike in the rest of Africa.[6]

Next, building on the finding from HF that it is variation in the growing-season-specific SPEI that induces conflict, we present estimates of the following regression specifically for the subsample of G5 Sahel countries:

$$conflict_{ict} = \alpha + \beta \, SPEI_{ict} + \gamma \, GS\_SPEI_{ict} + \nu \, X_{ic} + \eta_c + \tau_t + \epsilon_{ict}$$

where GS_SPEI_{ict} is a measure of the growing-season-specific SPEI, and the remaining terms are as described above (Table A2). This specification allows for the effect of growing-season SPEI measure on conflict to be estimated while controlling for overall SPEI for the year. If conflict is driven by climate-variation through a livelihoods channel, we would expect the growing-season-specific SPEI to have an effect on conflict. The results from Table A2 confirm this. After growing-season-SPEI is included in the specification, the coefficient on overall SPEI is small in magnitude and statistically insignificant, whereas the growing-season SPEI has a large and statistically significant coefficient. The results suggest that conflict occurrence reduces by 7.3 percentage points with a 1 unit increase in the growing-season-specific SPEI (Table A2 – column 5). Which in turn correlates with agricultural output.

These results underline that climate-induced variation in income/ food security is an important driver of conflict incidence, particularly for the countries in the Sahel region. Specifically, the incidence of conflict is found to be lower when there are favorable conditions for agricultural crops due to increased soil-moisture as measured by the growing-season SPEI.

5.2.1 The Spark? Conflict over Irrigated Land in the Sahel in the Aftermath of the Arab Spring

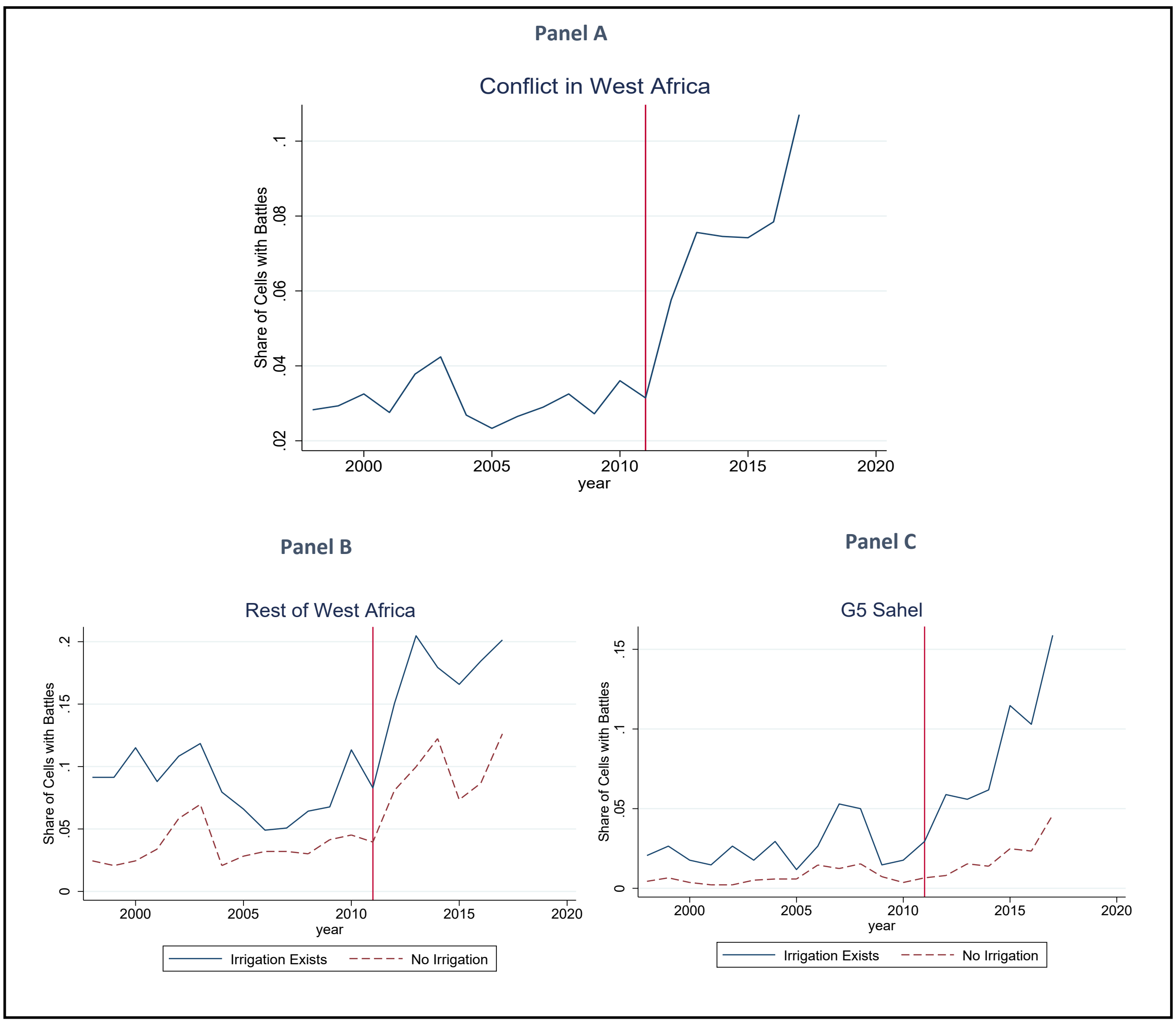
[5] The regression results are presented in Table A1. Column 1 contains the baseline estimates without any controls, with columns 2 – 4 sequentially adding the controls listed above. Column 5 additionally controls for common trends at the country-year level.

[6] A fan-regression plot of the partial relationship between SPEI and conflict from the specification in column 5 is plotted in Figure A3.

A corollary of the negative relationship between SPEI and conflict incidence would be that investments in infrastructure and technologies that reduce exposure to such climate-induced variability in the soil water, such as irrigation infrastructure, may reduce the risks of conflict. However, this section adds a nuance to this argument, presenting evidence documenting that such investments may make land a more valuable target and thus result in increased conflict incidence during times of heightened instability, especially in high-scarcity settings such as the Sahel.

This section exploits an exogenous increase in conflict in Western Africa in the post-2011 period, sparked in by events coinciding with the Arab Spring.[7] Trends in battle events from ACLED data in Western Africa over the period 1998 – 2017 show a sharp uptick in conflict events in Western Africa from 2011 onwards, in the aftermath of the Arab Spring (Figure 3, Panel A). It has been suggested that the Arab Spring, and in particular the fall of the Ghaddafi regime which supported various political and business interests in the Sahel region and other African countries, created a shift in the region's economic and political equilibrium

Figure 3: Conflict in Western Africa (1998 – 2017)



[7] Note that in the previous section, the analysis of conflict and SPEI data covered the period starting in 1998 and ending in 2011, i.e. before the post-Arab Spring induces a change in the political equilibrium of the region.

that may have sparked political unrest the region, particularly due to the looting of arms depots and through the return of mercenaries who had worked for the regime.[8]

Looking at the trends in conflict for the G5 Sahel countries and the rest of West Africa, and differentiating between irrigated and unirrigated land, an important difference is observed between the two regions with respect to the locations experiencing conflict breakout in the post-2011 period of heightened fragility (Figure 3, Panels B and C). Countries in the rest of Western Africa[9] experienced an uptick in conflict, but there is no differential trend based on irrigation availability, with both irrigated and non-irrigated cells experiencing similar increases in the probability of battle events occurring in the aftermath of the Arab Spring. In the G5 Sahel countries, however, the sharp increase in conflict in the post-Arab Spring period is concentrated in regions where irrigation exists, as demonstrated by the *differential trends* in the post-2011 period.

The graph in Panel B also shows an uptick in the rest of West Africa, which suggests that the experience of spillover conflict from the Arab Spring is not an experience unique to the G5 countries. To investigate this further, Figure A4 in the Appendix shows that this spike in conflict outside the G5 in the sample is driven largely by the rise in conflict in Nigeria. This coincides with the resurgence of militant activity in Nigeria during the same period, including increased violence by Boko Haram. Additionally, even in the case of Nigeria, there is still on *differential* in the likelihood of conflict arising in irrigated areas and non-irrigated areas in the post-Arab Spring period. The empirical approach here will hinge on this differential trend.

In addition to comparison with neighboring countries in West Africa, Figure A5 in the Appendix also shows the trends of conflict for the rest of Sub-Saharan Africa (excluding the G5 countries but including the rest of West Africa) and the countries of North Africa[10] to present a complete picture of conflict trends on the African continent. For Sub-Saharan Africa, no differential trends in conflict are observed, while a slight upward trend in overall conflict is seen, which begins prior to 2011. In the case of North Africa, however, a differential trend is observed between irrigated and non-irrigated regions following the Arab Spring. As will be shown in further results below, this is mainly driven by the concentration of population in irrigated regions in these countries but does not appear to be due to competition for resources. In all results that follow, this paper continues to present the countries in the rest of West-Africa as the preferred comparison group for the G5 Sahel countries due to their proximity to the G5 Sahel countries, but also presents results for the rest of Sub-Saharan Africa and North Africa.

This evidence suggests that in the G5 Sahel region irrigated areas experienced a much higher likelihood of conflict events following the exogenous increase in fragility in the aftermath of the Arab Spring.[11] As demonstrated in the earlier section, the specific agroclimatic context of the Sahel countries leaves the region more exposed to risks of conflict from climate induced income variation (albeit, in normal times). Irrigated land may hedge against such variability, but in this case, inequality in the benefits accrued from

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[8] See Siegle et al (2011) and Guillaumont et al. (2016).

[9] Note that to compare the effects of *geographic* spillovers from conflict in North Africa, section 5.2 focuses on neighboring countries in Western Sub-Sharan Africa as the appropriate comparison group due to their proximity to the G5 Sahel countries. The G5 countries are Burkina Faso, Chad, Mali, Mauritania and Niger. “Rest of West Africa” includes: Benin, Cameroon, Central African Republic, Côte d’Ivoire, Equatorial Guinea, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Senegal, Sierra Leone, and Togo. These are indicated on the top panel in Figure A2 in the Appendix.

[10] “North Africa” refers to Algeria, Djibouti, Arab Republic of Egypt, Libya, Morocco, and Tunisia.

[11] In comparison to non-irrigated regions in the same countries.

irrigation land appears to also raise the risk of conflict over land. Irrigated areas have higher predictability in terms of agricultural production as opposed to rainfed areas and the productivity gains from irrigation (or rents) are likely to be concentrated, making them more “lootable”. Thus, during periods of heightened fragility irrigated areas may be a “high-value” target for political groups engaged in conflict looking to gain income/ food security from land-grabs.

5.2.2 Empirical Approach: The Spark as a Shock

The presence of irrigation, however, may be correlated with various characteristics such as the presence of crops, local climate conditions and population density, which may be driving the observed differential trends in Figure 3. To control for these, the relationship between conflict and the presence of irrigation during the post-Arab Spring period of heightened fragility is next examined in a difference-in-difference framework through an empirical specification that that controls for covariates of irrigation that might be influencing the observed differential trends. Specifically, the following regression is estimated:

$$conflict_{ict} = \beta \ \ln(irrigarea_i + 1) \times Post_t + \gamma_t \boldsymbol{X_i} + \omega \boldsymbol{W_{it}} + \delta_{ct} + \alpha_i + \epsilon_{ict}$$

where the outcome of interest $\boldsymbol{conflict_{ict}}$ is an indicator variable that equals 1 if a battle event occurs in grid-cell $\boldsymbol{i}$ in country $\boldsymbol{c}$ in a given year $\boldsymbol{t}$. The variable $\boldsymbol{irrigarea_i}$ is a time-invariant measure of the area in each grid-cell $\boldsymbol{i}$ that was irrigated in the initial period, while $\boldsymbol{Post_t}$ is a dummy variable that takes on a value of 1 if t refers to the years after 2011.[12] The coefficient $\boldsymbol{\beta}$ captures the differential trend in conflict between cells with high-irrigation and low-irrigation grid-cells in the post-Arab Spring period. Additionally, $\boldsymbol{X_i}$ is a set of time-invariant cell-specific characteristics that may be correlated with the presence of irrigation and includes log of population at the start of the period as well as dummies to indicate the presence of wetlands, croplands, pasture lands, rivers and the homelands of ethnic groups that historically relied on agricultural livelihood strategies. γ_t allows for the effects of these characteristics to vary in flexible form over the period of the analysis. $\boldsymbol{W_{it}}$ is a vector of time-varying controls for rainfall and temperature to control for differences in climate over time and across grid-cells. Lastly δ_{ct} is a set of country-year fixed effects, and α_i a set of grid-cell fixed effects that account for average differences in other unobserved characteristics. All errors are clustered at the grid-cell level.[13]

Table A3 presents the results. For the G5 Sahel countries, there is a statistically significant and large positive increase in the likelihood of conflict breaking out in grid-cells where more irrigated land is observed and unchanged by multiple controls.[14] This is not found to be true for the rest of the countries in Western or Sub-Saharan Africa. The evidence does suggest the existence of differential trends in North Africa, which

[12] The use of $ln(irrigarea_i + 1)$ instead of $ln(irrigarea_i)$ is to ensure that gridcells with zero irrigation are not dropped from the analysis. Alternate specifications such as $ln(irrigarea_i + 0.1)$, $ln(irrigarea_i + 0.01)$, inverse hyperbolic sine of irrigated area (which is defined for zero) or the inclusion of a simple dummy to indicate the presence of any irrigation also produce similar results.

[13] In additional results not reported here, we also confirm that our results are robust to the use of standard errors estimated after accounting for spatial autocorrelation.

[14] See Table A3. Columns 1 – 4 sequentially include controls for country-year fixed effects, grid-cell fixed effects, time-invariant controls, as well as controls for weather. A stable coefficient indicates that the relationship is robust to the inclusion of a rich set of controls. Columns 5 – 8 and 9 – 12 estimate the same regression for the rest of Western Africa and the rest of Sub-Saharan Africa, and show that there is no differential change in conflict trends between irrigated and non-irrigated grid-cells in these countries. Columns 13 – 16 show the differential trends in North Africa, but the magnitude decreases by half after controls are added in columns 15 and 16.

was directly affected by the Arab Spring. However, the coefficient in this case is smaller and reduces by half after controlling for covariates such as population. Further results presented corroborate the role of population concentration as the main mechanism operating for North Africa, while in the G5 Sahel the presence of resource competition appears plays an additional role in amplifying conflict.

Additionally, to check the parallel trends assumption that underlies such difference-in-difference empirical approaches, we plot the year-specific coefficient attained from a similar specification as above, except by interacting $ln(irrigarea)$ with a separate indicator dummy for each year in the sample (Figure A6). Again, this is estimated separately for the G5 Sahel countries and the rest of the regions of Africa. The result confirms the existence of parallel trends in the period up until 2011. In the post-Arab Spring period, there is an increase in the likelihood of conflict where higher irrigation is observed specifically in the G5 Sahel countries (and in North Africa) but not in the rest of Western Africa nor in the rest of Sub-Saharan Africa. This robustness check provides further support to the hypothesis that highly irrigated land in the G5 Sahel, relative to non-irrigated land in the same region, is particularly more prone to conflict during periods of heightened fragility.[15]

5.2.3 Exploring Mechanisms through Heterogeneity

As suggested earlier, higher levels of irrigation may induce conflict through the changes in the distribution of land-based resources among the population in a given location. There are various channels through which irrigation-access can influence land resources and hence the likelihood of conflict. This section turns to a discussion of three possible channels to investigate mechanisms through which irrigated cells may be prone to conflict break-out in periods of heightened fragility. First, in the presence of denser settlements, population pressure during periods of heightened fragility could induce conflict between those that have access to irrigated land and those that do not. Second, irrigated lands may generate more inequality in areas where it redirects water from other land resources such as wetlands on which other livelihoods depend. Thirdly, extensive irrigation may generate inequalities particularly in regions where historically determined institutions have not developed mechanisms for the distribution of agricultural surpluses from land.

To investigate whether these channels do influence the likelihood of irrigated land experiencing more conflict during periods of heightened fragility we interact corresponding grid-cell characteristics with $ln(irrigarea_i) \times D_t$ in the above specification (Table A4). The interaction term with log of population is positive for the G5 Sahel and for North Africa, indicating that in both regions the increased likelihood of conflict occurs in irrigated land when it is accompanied by higher population densities. In fact, given the mean of log-population (5.34 for G5 Sahel and 3.47 for North Africa), this suggest that in a grid-cell with average population density there would be no significant increase in the likelihood of conflict post-Arab Spring in either region (since when log-population is zero, the coefficient is negative).

The wetlands channel is found to be unique to the Sahel. Indeed, we see that in the G5 Sahel it is precisely when wetlands are present that irrigated land experiences higher conflict, suggesting competition with alternative water resources that livelihoods depend on (Column 2 in Table A4). Such an effect is not observed in any of the other regions of the African continent. Furthermore, the coefficient on the

[15] Note the discussion focuses on relative differences in irrigation within similar regions. In particular, the difference in conflict observed between irrigated and non-irrigated land may also reflect the fact that the Sahel region has less irrigation when compared to other countries.

interactions with the share of each grid-cell that contains ethnic homelands of groups that historically relied on agricultural sources of livelihoods is significant and positive for the G5 Sahel. This indicates that conflict breaks out in the grid-cells with a higher historical share of agriculture reliant ethnicities, suggesting that irrigation increases the likelihood of conflict when the local ethnic groups had historically relied on agriculture as a livelihood strategy. It is plausible that historic institutions and local setups in these regions, where farming was largely subsistence-based in the past and traditionally remained in a cooperative equilibrium with transhumant pastoralists, did not evolve to manage the distribution of the large agricultural surpluses that accompany irrigation. A similar effect is found in the neighboring countries in West Africa (which likely reflect shared institutional history with G5 Sahel and the case of the Boko-Haram in Nigeria), but not for the other regions of Africa. On the contrary, the interaction term for North Africa has a negative effect, suggesting that irrigation infrastructure targeting is less likely when historically agricultural groups exist in this region, suggesting a historic adaptation of institutions of this region.

The inclusion of all interaction terms simultaneously does not change the signs or significance of the coefficients, suggesting that these channels operate independently (Table A4 – column 4). Again, similar results are not identified for countries outside the G5 Sahel, except for the case of non-agricultural ethnic homelands for the Rest of West Africa (Table A4 – column 5-8) and the role of population in North Africa (columns 13 – 16). In fact, for the rest of West Africa, in the absence of non-agricultural ethnic groups irrigation reduces the risk of conflict, but the presence of such homelands dampens this negative effect.

Taken together these results also point to the importance of local institutions for distributing the gains from shared resources (such as water) in determining how location characteristics, such as the presence of irrigation infrastructure, are associated with the risk of conflict breaking out in periods of heightened fragility.

6. Conclusion/ Discussion

The results presented in this paper bring new insights on the evolving evidence base surrounding the linkages between water and fragility and inform on their spatial and temporal variations. While water is widely recognized as critical to development, economic research on its systematic – rather than by sub-sector - contribution has been limited. This is particularly the case in fragile countries where data gaps further curtail opportunities for quantitative research. In this context, this paper makes three main contributions.

First, it provides a newer and more granular perspective of the role of water with respect to fragility in the G5 Sahel. The fluid definition of the Sahel (OECD/ SWAC, 2014) presents a challenge when it comes to research as it leads to different definitions being used, some administrative ones mixing groups of countries with widely different ratios of Sahelian territory, to various geo-climatic definitions (ex. cram-cram limit or isohyets limits), all of which results in rendering impossible any comparison of the limited existing research. By choosing to focus on the G5 Sahel countries, we use a definition that is both geographically and strategically congruent with policy relevance.

Second, the findings bear high importance for food security in fragile regions such as the Sahel. None of the countries of the Sahel are food self-sufficient, making them vulnerable to climate variability. Rural areas tend to be the hardest hit – with negative impacts on agricultural incomes, rural livelihoods, and survival in general. Conflict may arise in response to such insecurity, and may further reduce food production, disrupt supply chains and impact both formal and non-formal social protection systems. In providing a more spatially and temporally informed focus on a vulnerable area, the results underscore the need to revisit the dynamics between water and food-security in fragile contexts where many people live close to subsistence levels. The results also identify specific situational contexts where policy interventions targeted at protecting livelihoods and ensuring food-security, especially in times of crisis, may inadvertently perpetuate fragility rather than attenuate it.

Third, the research highlights the specific vulnerability of irrigated areas during periods of heightened fragility – which warrants appropriate policy consideration in the preparation of new interventions, both in the context of a surge in funding for the Sahel region in particular and also as part of COVID-19 recovery efforts more broadly. Few development levers can be activated like those in the water sector to respond to concerns ranging from protecting livelihoods, enhancing food security, generating employment opportunities for vulnerable groups, and protecting human capital and public health. Yet, water infrastructure tends to be costly with a high locked-in effect. For those reasons, it is essential to ensure that the deployment and design of interventions and infrastructure accounts for the existing local context and potential externalities, an issue that is all the more critical within the larger context of climate change.

One final contribution of this research is its demonstration of the need to continue pushing research even on issues considered or perceived to be well established, particularly in the case of water, a primordial foundation of development. The findings show that the systematic use of existing and new data can bring new insights and inform policy with required nuances in complex settings.

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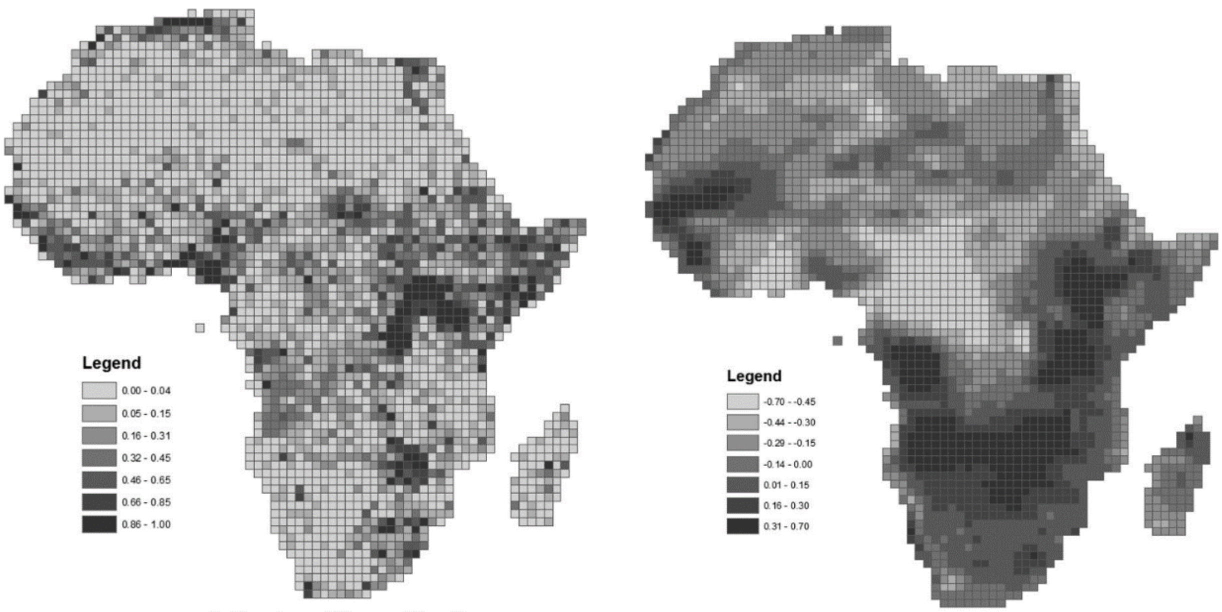
APPENDIX: Tables and Figures:

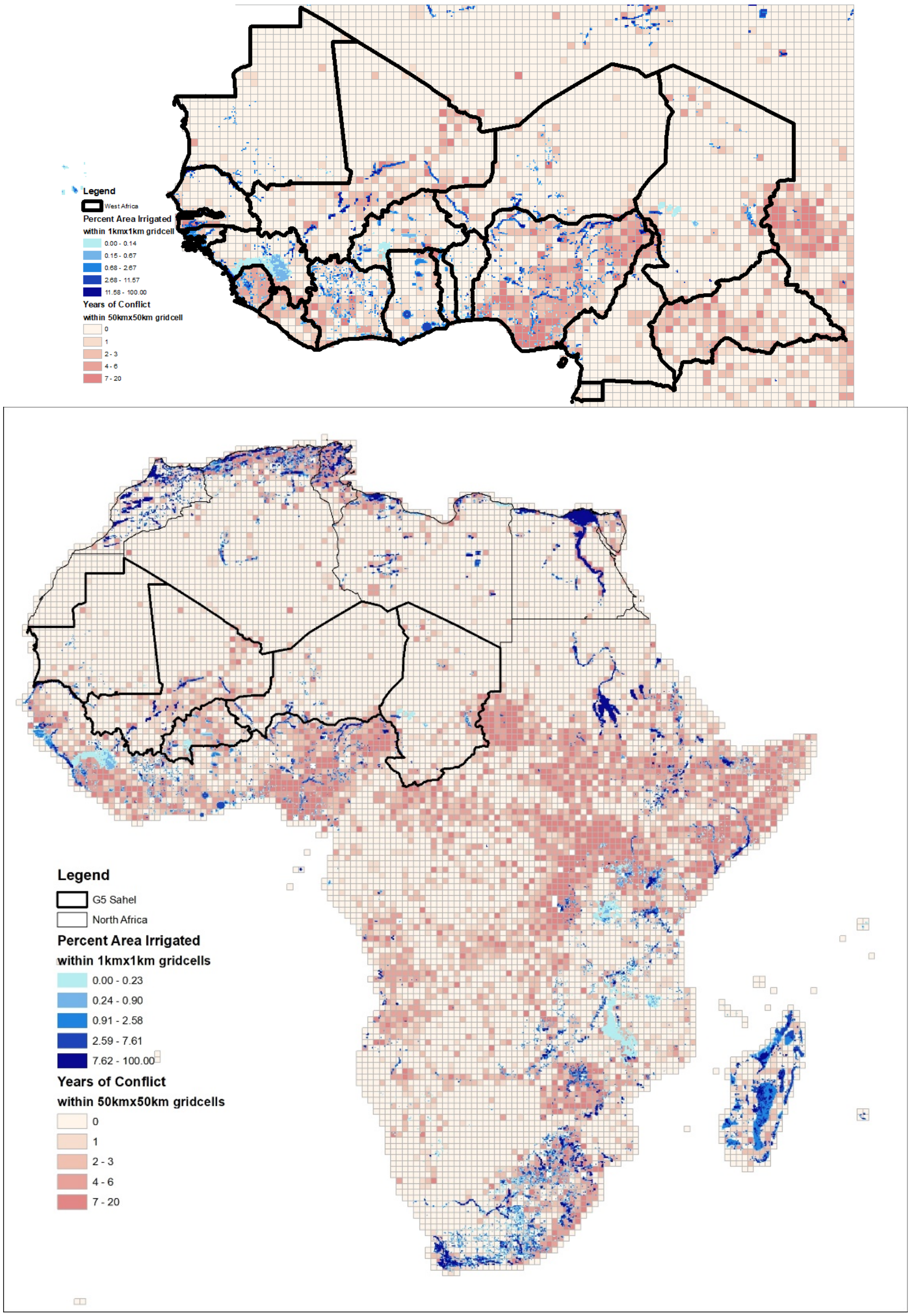
Figure A1: Gridded Data on Conflict and SPEI (1997-2011). Source: Harrari and Ferrara (2018)



A. Fraction of Years with at Least One Conflict Event, 1997−2011

B. Average SPEI, 1997−2011

Figure A2: Irrigated Area from FAO (pre-2005), and conflict events data from Armed Conflict & Event Data Project (ACLED), https://www.acleddata.com, for the whole continent of Africa.



Note: The five G5 Sahel countries are Burkina Faso, Chad, Mali, Mauritania, and Niger. North Africa refers to Algeria, Djibouti, Arab Republic of Egypt, Libya, Morocco, and Tunisia.

Table A1: Conflict and SPEI in Africa

Dependent Variable:	Dummy Indicator for Any Conflict in a Year				
	(1)	(2)	(3)	(4)	(5)
SPEI	0.0154***	-0.00524	-0.00860*	-0.00546	0.00672
	(-0.00555)	(-0.00503)	(-0.00442)	(-0.00464)	(-0.0068)
SPEI X G5 Sahel	-0.0580***	-0.0282***	-0.0161*	-0.0200**	-0.0359***
	(-0.0106)	(-0.01)	(-0.00924)	(-0.00934)	(-0.0131)
N	37095	37095	37095	37095	37095
R-sq	0.017	0.086	0.189	0.192	0.253
Controls	N	Y	Y	Y	Y
Country FE	N	N	Y	Y	Y
Year FE	N	N	N	Y	Y
Country-Year FE	N	N	N	N	Y

The dependent variable is a dummy equal to one if any conflict event occurred in a grid-cell in a given year. The SPEI is the standardized precipitation-evapotranspiration index. Controls include the following time-invariant cell characteristics (also used by HF in their specification): terrain, elevation, cell area, presence of roads, distance to river, presence of a country border, presence of any mineral resources and a measure of ethno-linguistic fractionalization. Standard errors in parentheses clustered at the grid-cell level

* p<0.1, ** p<0.05, *** p<0.01

Figure A3: Relationship between contemporaneous conflict and SPEI, G5 Countries and the Rest of Africa. The figure shows a locally-linear polynomial regression through residuals obtained by partialling out cell characteristics and country-year fixed effects.

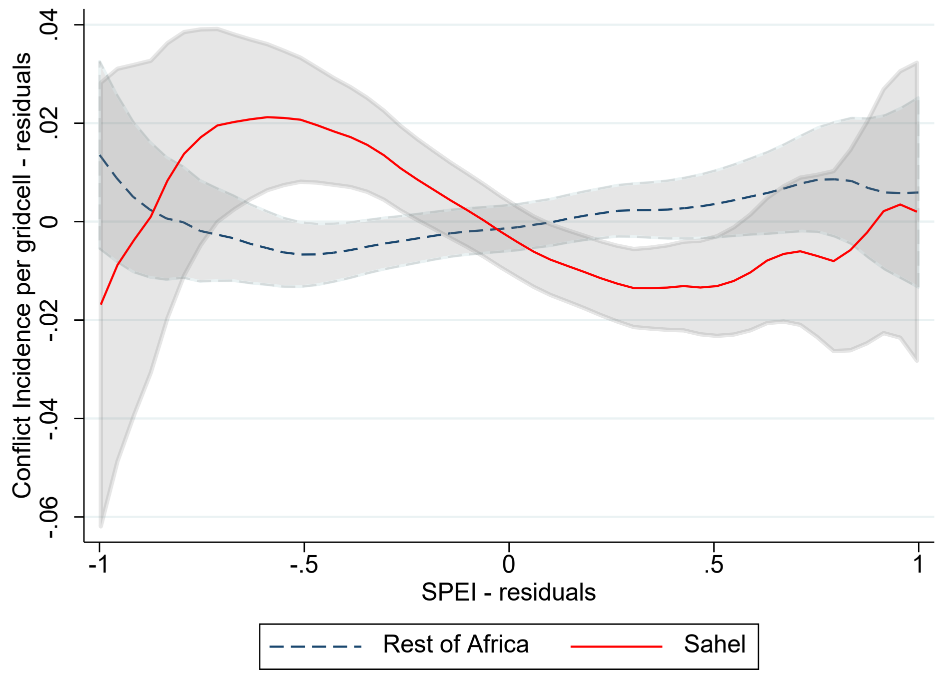


Table A2: Growing Season SPEI in G5 Sahel Countries

Dependent Variable:	Any Conflict during Year				
	(1)	(2)	(3)	(4)	(5)
SPEI	-0.00225	-0.00533	-0.00341	-0.00369	-0.0139
	(-0.00745)	(-0.00662)	(-0.00677)	(-0.0072)	(-0.00986)
SPEI in Growing Season	-0.171***	-0.116***	-0.0986***	-0.0973***	-0.0728**
	(-0.0303)	(-0.0265)	(-0.0248)	(-0.026)	(-0.029)
N	6090	6090	6090	6090	6090
R-sq	0.021	0.068	0.072	0.08	0.107
Controls	N	Y	Y	Y	Y
Country FE	N	N	Y	Y	Y
Year FE	N	N	N	Y	Y
Country-Year FE	N	N	N	N	Y

The dependent variable is a dummy equal to one if any conflict event occurred in a grid-cell in a given year. The SPEI is the standardized precipitation-evapotranspiration index. Controls include the following time-invariant cell characteristics (also used by HF in their specification): terrain, elevation, cell area, presence of roads, distance to river, presence of a country border, presence of any mineral resources and a measure of ethno-linguistic fractionalization. Standard errors in parentheses clustered at the grid-cell level

* p<0.1, ** p<0.05, *** p<0.01

Figure A4: Battle events in Western Africa (1998 – 2017), by irrigation presence.

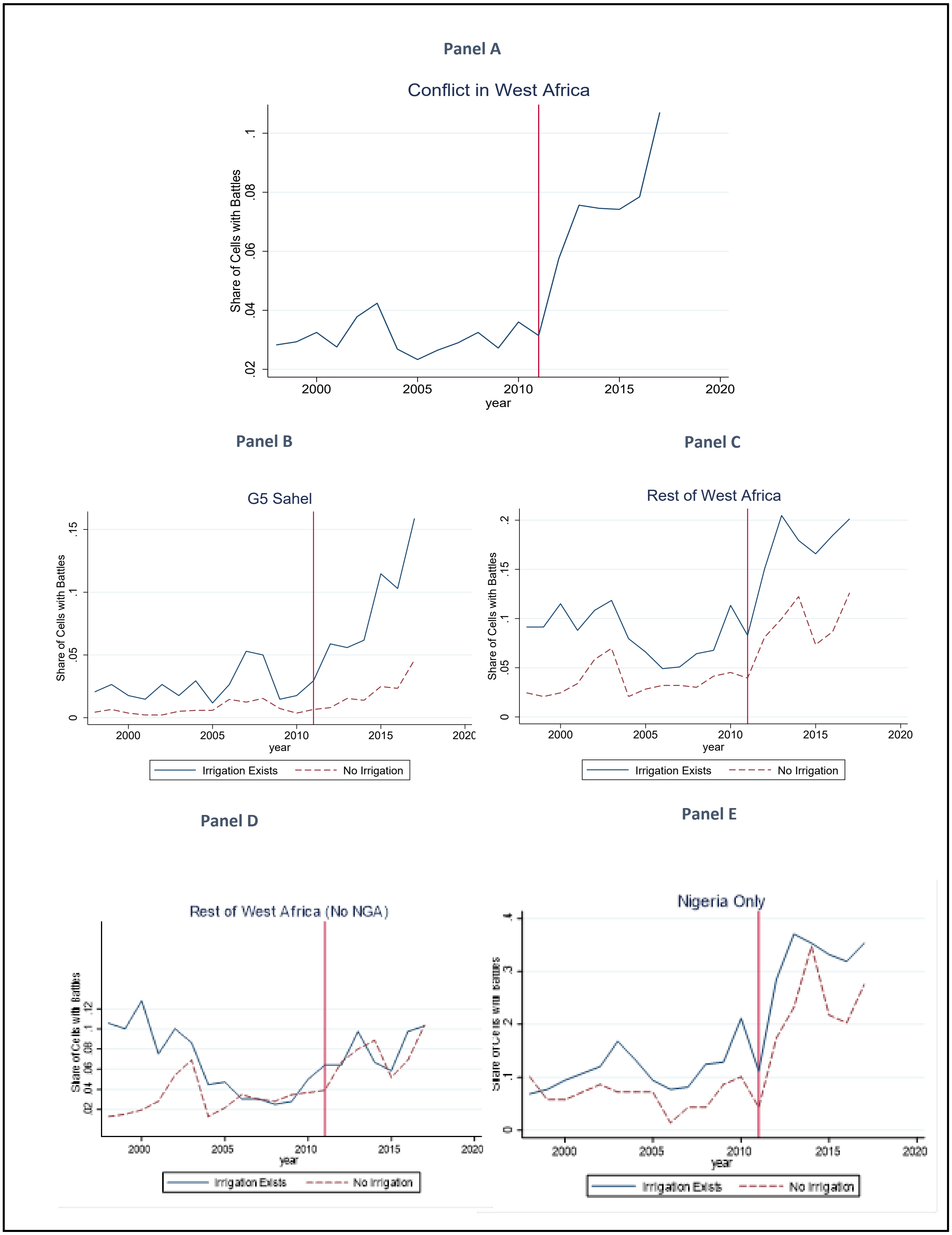


Figure A5: Battle events in the subregions of the African continent (1998 – 2017), by irrigation presence. The G5 countries are Burkina Faso, Chad, Mali, Mauritania and Niger. "Rest of West Africa" includes: Benin, Cameroon, Central African Republic, Cote d'Ivoire, Equatorial Guinea, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Senegal, Sierra Leone, and Togo. North Africa refers to Algeria, Djibouti, Arab Republic of Egypt, Libya, Morocco, and Tunisia.

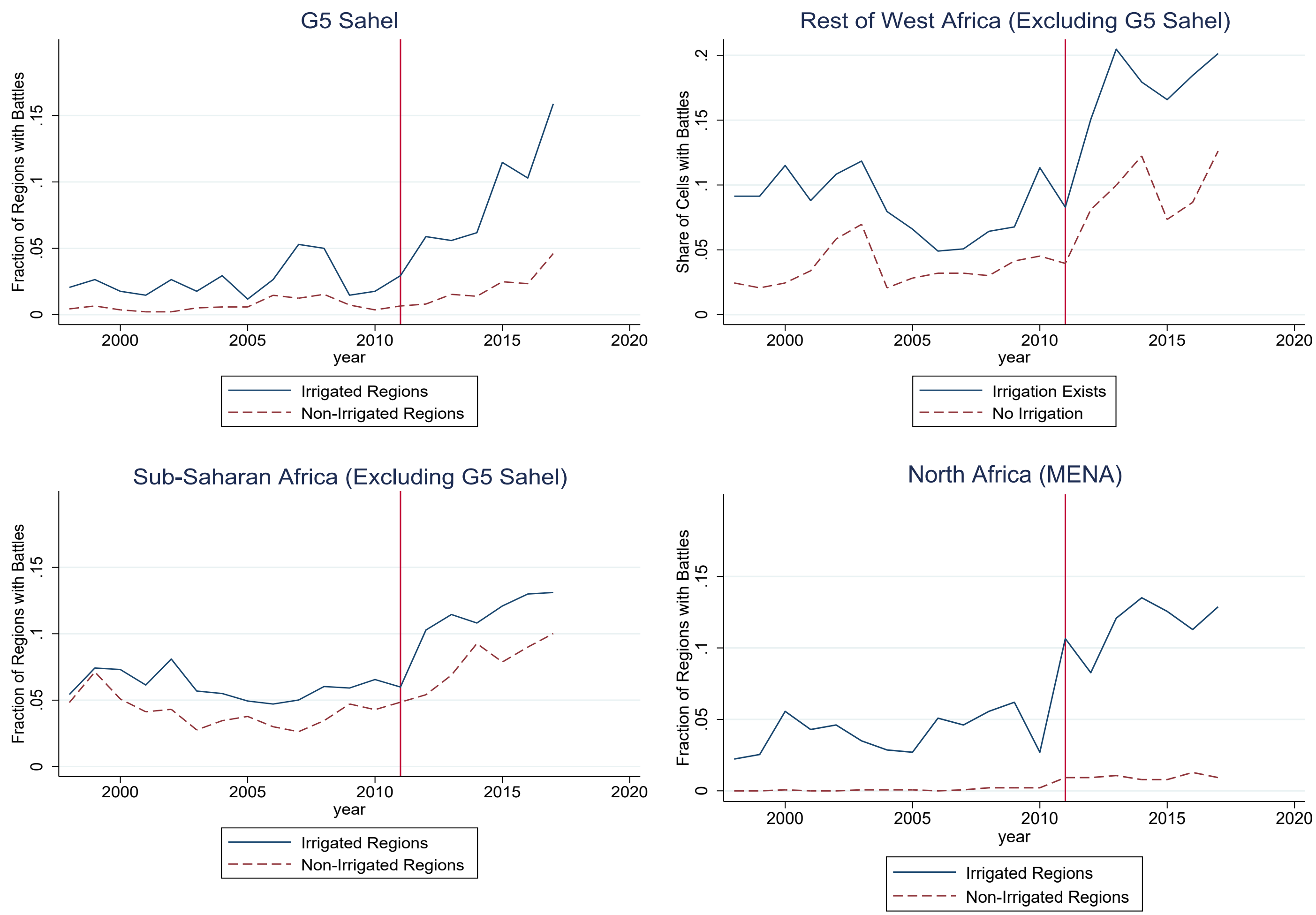


Table A3: Conflict in Irrigated Regions after the Arab Spring in the G5 Sahel and Rest of Africa

Dependent Variable:	Dummy =1 if any BATTLE in a cell-year							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	G5 Sahel				Rest of West Africa (excluding G5)			
ln(Irrigated Area) X Post	0.0582***	0.0582***	0.0471***	0.0470***	0.0125	0.0125	-0.00087	-0.00078
	(0.0108)	(0.0108)	(0.011)	(0.011)	(0.0122)	(0.0122)	(0.0129)	(0.0128)
Observations	34160	34160	34160	34160	22440	22440	22440	22440
Number of Clusters (Grid-cells)	1708	1708	1708	1708	1122	1122	1122	1122
R-sq	0.066	0.226	0.234	0.234	0.125	0.335	0.346	0.347
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Cell FE		Y	Y	Y		Y	Y	Y
Controls X Time			Y	Y			Y	Y
Climate Controls				Y				Y
Mean Conflict	0.0181	0.0181	0.0181	0.0181	0.0856	0.0856	0.0856	0.0856

Each observation corresponds to a 50km x 50km grid-cell observed in a given year between 1998 and 2017. The outcome variable is a dummy variable indicating that the grid-cell experienced a battle event in a given year, as reported in the ACLED dataset. Irrigated area is measured as the percentage share of an average plot of land that is equipped for irrigation, as documented by Siebert et al (2015). Controls include log of population at the start of the period as well as dummies to indicate the presence of wetlands, croplands, pasture lands, rivers and the homelands of ethnic groups that historically relied on agricultural livelihood strategies. Standard errors in parentheses clustered at the grid-cell level. Climate controls include mean temperature and log of total rainfall in the wet and dry seasons. * p<0.1, ** p<0.05, *** p<0.01.

Table A3 (continued): Conflict in Irrigated Regions after the Arab Spring in the G5 Sahel and Rest of Africa

Dependent Variable:	Dummy =1 if any BATTLE in a cell-year							
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Rest of SSA (excluding G5)				North Africa (MENA)			
ln(Irrigated Area) X Post	0.00483	0.00483	-0.00417	-0.00396	0.0504***	0.0504***	0.0255***	0.0254***
	(0.00322)	(0.00322)	(0.00344)	(0.00345)	(0.00651)	(0.00651)	(0.00682)	(0.00681)
Observations	127800	127800	127580	127580	40560	40560	40540	40540
Number of Clusters (Grid-cells)	6379	6379	6379	6379	2028	2028	2028	2028
R-sq	0.136	0.369	0.372	0.372	0.115	0.389	0.407	0.407
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Cell FE		Y	Y	Y		Y	Y	Y
Controls X Time			Y	Y			Y	Y
Climate Controls				Y				Y
Mean Conflict	0.0635	0.0635	0.0635	0.0635	0.0233	0.0233	0.0233	0.0233

Each observation corresponds to a 50km x 50km grid-cell observed in a given year between 1998 and 2017. The outcome variable is a dummy variable indicating that the grid-cell experienced a battle event in a given year, as reported in the ACLED dataset. Irrigated area is measured as the percentage share of an average plot of land that is equipped for irrigation, as documented by Siebert et al (2015). Controls include log of population at the start of the period as well as dummies to indicate the presence of wetlands, croplands, pasture lands, rivers and the homelands of ethnic groups that historically relied on agricultural livelihood strategies. Standard errors in parentheses clustered at the grid-cell level. Climate controls include mean temperature and log of total rainfall in the wet and dry seasons. * p<0.1, ** p<0.05, *** p<0.01.

Figure A6: Event-study analysis. The graphs present estimates of year-specific coefficients of ln(irrigarea) and the 95 percent confidence interval for the different sub-regions of Africa, using a specification similar to that employed in Table A3.

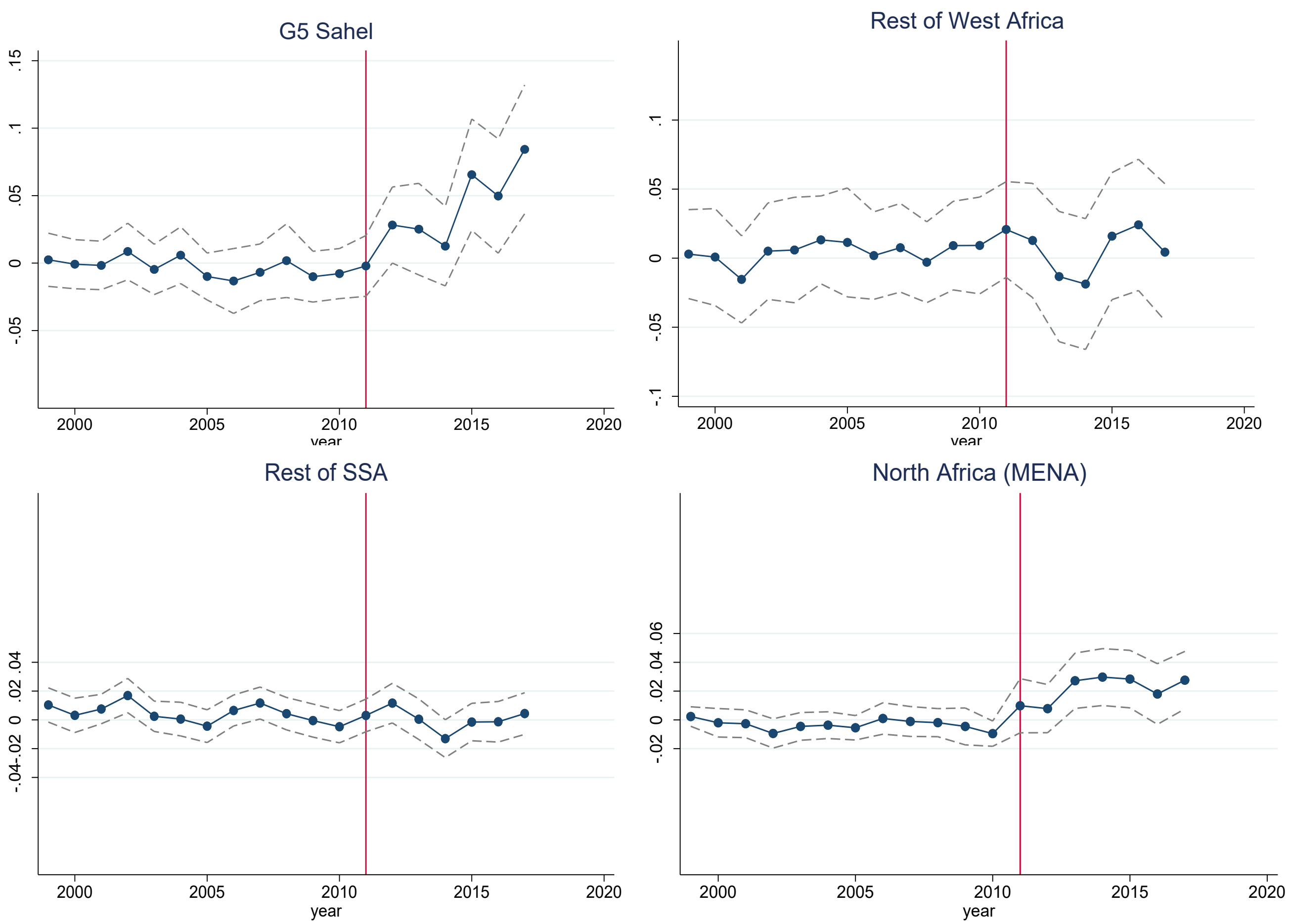


Table A4: Exploring Mechanisms for Conflict in Irrigated Lands

Dependent Variable:	Dummy =1 if any BATTLE in a cell-year							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	G5 Sahel				Rest of West Africa (excluding G5)			
Ln(Share Irrigated) X Post	-0.0773**	-0.015	0.0103	-0.158***	0.0669	0.00452	-0.0533***	0.0176
	(0.0361)	(0.0123)	(0.0198)	(0.0429)	(0.0481)	(0.0163)	(0.0176)	-0.0471)
…X Post X Ln(pop)	0.0118***			0.0103***	(0.00594			-0.00675
	(0.00373)			(0.00349)	(0.00421			(0.00445)
… X Post X Wetland		0.0718***		0.0709***		-0.00748		0.00687
		(0.0166)		(0.0168)		(0.0213)		(0.0233)
… X historically Agricultural Ethnic Homeland			0.0521*	0.0503*			0.0857***	0.0876***
			(0.027)	(0.0264)			(0.028)	-0.029)
Observations	34160	34160	34160	34160	22440	22440	22440	22440
R-sq	0.236	0.236	0.235	0.239	0.347	0.347	0.347	0.348
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Cell FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls X Time	Y	Y	Y	Y	Y	Y	Y	Y
Climate Controls	Y	Y	Y	Y	Y	Y	Y	Y

Each observation corresponds to a 50km x 50km grid-cell observed in a given year between 1998 and 2017. The outcome variable is a dummy variable indicating that the grid-cell experienced a battle event in a given year, as reported in the ACLED dataset. Irrigated area is measured as the percentage share of an average plot of land that is equipped for irrigation, as documented by Siebert et al (2015). Controls include log of population at the start of the period as well as dummies to indicate the presence of wetlands, croplands, pasture lands, rivers and the homelands of ethnic groups that historically relied on agricultural livelihood strategies. Standard errors in parentheses clustered at the grid-cell level. Climate controls include mean temperature and log of total rainfall in the wet and dry seasons.
* p<0.1, ** p<0.05, *** p<0.01"

Table A4 (continued): Exploring Mechanisms for Conflict in Irrigated Lands

Dependent Variable:	Dummy =1 if any BATTLE in a cell-year							
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Rest of SSA (excluding G5)				North Africa (MENA)			
Ln(Share Irrigated) X Post	-0.000559	0.000723	-0.00917*	-0.00115	-0.0171**	0.0226**	0.0490***	0.000587
	(0.00837)	(0.00471)	(0.00474)	(0.00978)	(0.0076)	(0.00888)	(0.00989)	(0.00993)
…X Post X Ln(pop)	-0.000397			-0.000265	0.00626***			0.00855***
	(0.000864)			(0.000865)	(-0.00116)			(0.00126)
… X Post X Wetland		-0.00822		-0.00807		0.00975		-0.00265
		(0.00562)		(0.00561)		(0.00976)		(0.00888)
… X historically Agricultural Ethnic Homeland			0.00877	0.0088			-0.0375***	-0.0622***
			(0.00701)	(0.00702)			(0.012)	(0.0123)
Observations	127580	127580	127580	127580	40540	40540	40540	40540
R-sq	0.372	0.372	0.372	0.372	0.409	0.405	0.407	0.415
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Cell FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls X Time	Y	Y	Y	Y	Y	Y	Y	Y
Climate Controls	Y	Y	Y	Y	Y	Y	Y	Y

Each observation corresponds to a 50km x 50km grid-cell observed in a given year between 1998 and 2017. The outcome variable is a dummy variable indicating that the grid-cell experienced a battle event in a given year, as reported in the ACLED dataset. Irrigated area is measured as the percentage share of an average plot of land that is equipped for irrigation, as documented by Siebert et al (2015). Controls include log of population at the start of the period as well as dummies to indicate the presence of wetlands, croplands, pasture lands, rivers and the homelands of ethnic groups that historically relied on agricultural livelihood strategies. Standard errors in parentheses clustered at the grid-cell level. Climate controls include mean temperature and log of total rainfall in the wet and dry seasons.

* p<0.1, ** p<0.05, *** p<0.01"